Faculty of Mechanical and Manufacturing Engineering Technology

THERMAL AND MECHANICAL PROPERTIES OF THERMOPLASTIC CASSAVA STARCH/BEESWAX REINFORCED WITH COGON GRASS FIBER

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Bachelor of Manufacturing Engineering Technology
(Process and Technology) with Honours

2019

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This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Manufacturing Engineering Technology (Process and Technology) with Honours.

FACULTY OF MECHANICAL AND MANUFACTURING ENGINEERING TECHNOLOGY

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

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APPROVAL

This report is submitted to the Faculty of Mechanical and Manufacturing Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering Technology (Process & Technology) with Honours. The member of the supervisory is as follow:

Signature	:……………..
Supervisor Name	: Dr Ridhwan Bin Jumaidin.
Date	:…………………….. ....

DEDICATION

To

My Mother

A strong and gentle soul who taught me to trust in Allah, believe in hard work and that so much could be done with little.

My Father

For earning an honest living for us and for supporting and encouraging me to believe in myself.

My Supportive Siblings

For their love, endless support and best pray.

ABSTRACT

Nowadays, the concern about the environmental are rapidly growing. Non-biodegradable and environmental pollution are the side effects of the problem of the petroleum-based polymer. In order to overcome this critical issues, various types of materials that are more environmentally friendly were developed. Renewable bio-polymer is one of the promising materials that can be an alternative to petroleum-based polymer substitution as it is quickly biodegradable and more environmentally sustainable. Starch is one of the bio-polymer examples in the biodegradable polymer because of its abundant resources, low cost, biodegradability and renewability. However, the starch has poor mechanical and thermal properties. Proper modifications should therefore be implemented to enhance the properties of this material. Fibers act as reinforcement in fiber-reinforced composite materials by providing strength and rigidity in the structure. Cogon grass fiber (also known as *imperata cylindrica*) is a rhizomatized, permanent pantropical herb, which takes on the advantage of moist, short, severe, dry seasonal alternating conditions typical of southeastern Asia. Cogon grass is cheap and attractive feedstock to be used in feed and production of bioenergy. It has the potential to be utilized as reinforcement agent for producing bio-based composite. The objectives of this study were to develop thermoplastic cassava starch/beeswax reinforced with cogon grass fiber, second to investigate the thermal properties of thermoplastic cassava starch/beeswax reinforced with cogon grass fiber and lastly to determine the mechanical properties cassava starch/beeswax reinforced with cogon grass fiber. In this study, modified TPCS/beeswax been used as the matrix. Modification has been carried out for improving the properties of the Thermoplastic Cassava Starch (TPCS) by incorporating it with various amounts of cogon grass fiber (CGF), i.e. 10, 20, 30, and 40wt.%, respectively. TPCS/beeswax reinforced with GCF composite were developed by using high speed mixing at 1200 rpm for 6 min approximately and hot press method at 145°C for 1 hour by maintaining the composition of starch and glycerol at ratio 80:20 respectively. Then the thermal properties of the composite were investigated by performing the TGA and DSC test. The findings showed that the thermal properties of the composite were slightly improved as the CGF content increase from (10% to 40% wt.%). Besides that, the mechanical properties of the composite were evaluated by executing the tensile, impact and flexural test. The results showed that the tensile strength and tensile modulus increased significantly with the addition of the CGF. However, only the elongation at break showed a decreased pattern following the increasing content of CGF compared to the 0% of fiber content. Other than that, the impact and flexural properties also produced positive findings where the introduction of CGF increase the flexural strength, flexural modulus, and impact strength of the material. These improvements were in accordance with the findings from the FT-IR and SEM that shows the TPCS/beeswax and the CGF were compatible and managed to form a homogenous structure. In general, the findings from this study have shown that the TPCS/beeswax reinforced with the CGF composite has improved the function at characteristic compared to the original material. In conclusion, the TPCS /beeswax reinforced

with CGF composite are highly potential to be marketed in packaging industry as single-use tray. It is applicable as green handphone casing, card holder and any suitable packaging tray.

ABSTRAK

Hari demi hari, kebimbangan mengenai masalah alam sekitar semakin meningkat. Masalah sisa yang tidak boleh terurai dan pencemaran alam sekitar adalah kesan sampingan masalah polimer berasaskan petroleum. Untuk mengatasi masalah kritikal ini, pelbagai jenis bahan yang lebih mesra alam telah dihasilkan. Bio-polimer yang diperoleh daripada sumber yang boleh diperbaharui adalah salah satu bahan yang boleh menjadi alternatif kepada penggantian polimer berasaskan petroleum kerana ia lebih mudah terurai dan mesra alam sekitar. Kanji ialah salah satu contoh bio-polimer dalam polimer yang mudah terurai kerana sumbernya yang banyak, kos rendah, mudah terurai dan boleh diperbaharui. Walau bagaimanapun kanji mempunyai kelemahan dan kekurangan daripada segi termal dan ketahanan sifat mekanikal. Oleh itu, pengubahsuaian yang sewajarnya perlu dilaksanakan untuk meningkatkan sifat-sifat bahan ini. Serat bertindak sebagai penguat dalam bahan komposit bertetulang serat dengan menyediakan kekuatan dan kekerasan dalam struktur. Serat daripada lalang (juga dikenali sebagai *imperata cylindrica*) adalah tumbuhan hijau yang tumbuh meliar di merata tempat, yang mampu tumbuh dalam cuaca yang panas dan kering terutama di kawasan Asia Tenggara. Lalang adalah tumbuhan yang mudah didapati dan ringkas untuk digunakan makanan haiwan dan pengeluaran bioenergi yang berpotensi untuk digunakan sebagai ejen penguat untuk menghasilkan komposit yang mudah terurai. Objekif bagi kajian ini adalah untuk membentuk Termoplastik Kanji Ubi Kayu (TPCS)/ lilin lebah yang diperkuat dengan serat lalang, yang seterusnya ialah untuk mengkaji sifat termal TPCS / lilin lebah yang diperkuat dengan GCF dan terakhir untuk tentukan sifat mekanikal TPCS / lilin lebah yang diperkuat dengan GCF. Dalam kajian ini, pengubahsuaian TPCS / lilin lebah dari kajian sebelumnya telah digunakan sebagai matriks. Pelbagai kaedah pengubahsuaian digunakan untuk meningkatkan sifat-sifat Termoplastik Kanji Ubi Kayu (TPCS) dengan mencampurkannya dengan pelbagai jumlah serat lalang (CGF), 10, 20, 30, dan 40wt.% mengikut turutan. Oleh itu, TPCS / lilin lebah yang diperkuat dengan komposit GCF telah dihasilkan dengan menggunakan pencampuran berkelajuan tinggi pada 1200 rpm selama kira-kira 6 minit dan kaedah pengacuan mampatan panas pada suhu 145 ° C selama 1 jam dengan mengekalkan komposisi kanji dan gliserol pada nisbah 80:20. Kemudian sifat termal komposit ini disiasat dengan melaksanakan ujian TGA dan DSC. Penemuan menunjukkan bahawa sifat termal komposit meningkat sedikit demi sedikit apabila kandungan CGF meningkat dari (10% hingga 40% wt.%). Selain itu, sifat mekanik komposit juga diuji dengan melaksanakan ujian tegangan, impak dan lenturan. Keputusan menunjukkan bahawa kekuatan tegangan dan modulus tegangan meningkat dengan ketara dengan penambahan CGF. Walau bagaimanapun, salah satu sifat mekanikal iaitu penegangan di bahagian hujung menunjukkan corak penurunan berikutan kandungan CGF yang meningkat berbanding 0% kandungan serat. Selain itu, sifat impak dan sifat lenturan juga menghasilkan keputusan yang baik di mana kehadiran CGF juga terbukti dengan peningkatan kekuatan lenturan, modulus lenturan, dan kekuatan impak. Peningkatan ini adalah selaras dengan penemuan dari FT-IR dan SEM yang menunjukkan TPCS / beeswax dan CGF yang serasi dan berjaya membentuk struktur homogen. Secara umumnya, penemuan dari kajian ini

menunjukkan bahawa TPCS / lilin lebah yang diperkuat dengan komposit CGF telah meningkatkan sifat komposit tersebut berbanding dengan bahan asal. Sebagai kesimpulan, TPCS / lilin lebah yang diperkuat dengan komposit CGF sangat berpotensi untuk dipasarkan dalam industri pembungkusan sebagai dulang untuk kegunaan sekali. Selain itu, sangat berpotensi sebagai sarung telefon bimbit, bekas kad dan pelbagai bentuk dulang pembungkusan yang sesuai.

ACKNOWLEDGEMENTS

First and foremost, praises and thanks to Allah S.W.T., the Almighty, for His showers of blessings throughout my research project to complete this bachelor's degree project successfully.

I would like to express my deep and sincere gratitude to my research supervisor, Dr. Ridhwan Bin Jumaidin for giving me the opportunity to do this research and providing invaluable guidance throughout the journey for me to complete this research. His dynamism, vision, sincerity and motivation have deeply inspired me to work harder to excel this research. It was a great privilege and honor for me to work and study under his guidance. I am extremely grateful for what he has offered me. I also would like to thank him for his friendship, empathy and great sense of humor.

Also, I would like to thank Mr. Azizul Ikhwan Bin Mohd for his assistance during my work at the material testing laboratory. He diligently guided me whenever my research involves the equipment from the material testing laboratory. I will forever be in his debt. Besides that, I am also extremely grateful to my parents for their love, prayers caring and sacrifices for educating and preparing me for my future. I am very much thankful to my siblings for their endless support and motivation. Last but not least, my special thanks belong to my friends who helped me and voluntarily involved to complete this research successfully.

TABLE OF CONTENTS

	PAGE
DECLARATION	**i**
APPROVAL	**ii**
DEDICATION	**iii**
ABSTRACT	**iv**
ABSTRAK	**vi**
ACKNOWLEDGEMENTS	**viii**
LIST OF TABLES	**xii**
LIST OF FIGURES	**ii**
LIST OF ABBREVIATIONS	**vi**
CHAPTER	
1. INTRODUCTION	**1**
1.1 Background	1
1.2 Problem Statement	2
1.3 Objectives	3
1.4 Significance of Study	4
1.5 Scope	5
1.6 Structure	5
2. LITERATURE REVIEW	**7**
2.1 Introduction	7
2.2 Natural Fiber	7
2.2.1 Cogon Grass Fiber	10
2.2.2 Other Natural Fiber	11
2.3 Starch	14
2.4 Biopolymer	16
2.5 Composite	19
2.5.1 Polymer Matrix Composite (PMC)	21
2.5.2 Metal Matrix Composite (MMC)	22
2.5.3 Ceramic Matrix Composite (CMC)	23
2.6 Natural Fiber Reinforced Composite	25

2.7 Thermoplastic Starch 26
2.7.1 Thermoplastic Cassava Starch 27
2.7.2 Thermoplastic Rice Starch 36
2.7.3 Thermoplastic Potato Starch 38
2.8 Application of Thermoplastic Starch 42
2.9 Wax 43
2.9.1 Beeswax 44
2.10 Summary 45

3. METHODOLOGY 47
3.1 Introduction 47
3.2 Materials 49
3.2.1 Cogon Grass Fiber 49
3.2.2 Cassava Starch 51
3.2.3 Glycerol 52
3.2.4 Beeswax 54
3.3 Preparation of Thermoplastic Cassava Starch (TPCS) Mixture 55
3.4 Preparation of TPCS/Beeswax Mixture 56
3.5 Fabrication of TPCS/Beeswax Reinforced with Cogon Grass Fiber 57
3.6 Characterization of Samples 60
3.6.1 Thermal Testing 60
3.6.2 Mechanical Testing 62
3.6.3 Others 65

4. RESULTS AND DISCUSSION 67
4.1 Introduction 67
4.2 Thermal Analysis 68
4.2.1 Thermo-gravimetric Analysis (TGA) 68
4.2.2 Differential Scanning Calorimetry (DSC) 71
4.3 Mechanical Analysis 72
4.3.1 Tensile Properties 72
4.3.2 Flexural Properties 75

4.3.3 Impact Properties 77
4.4 Others 79
4.4.1 Fourier Transform Infrared Spectroscopy (FTIR) 79
4.4.2 Scanning Electron Microscope (SEM) 81
4.5 Product Innovation 84

5. CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH 85
5.1 Conclusion 86
5.2 Recommendations for Future Research 88
5.3 Project Potential 88

REFERENCES 89
APPENDICES 99

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Natural fibers in the world and world production	12
2.2	Natural fiber composite applications in industry	13
2.3	Amylose content and structure in selected starches	16
2.4	The classification of three main group of biopolymers	17
2.5	Tensile data of resins and laminates	25
2.6	Tensile mechanical properties and Impact properties for the all tested samples	30
2.7	Summary of TPCS Composite from Various Studies	35
2.8	Summary of TPRS Composite from Various Studies	37
2.9	Tensile Properties of Polypropylene and its Composites as Functions of Starch Content	39
2.10	Summary of Thermoplastic Potato Starch Composite from Various Studies	41
3.1	General Analysis Content for Cassava Starch	50
3.2	Specifications of Glycerol.	52
3.3	Specification of Beeswax.	53
3.4	Calculation for Fiber	57

LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	Classification of natural fibers	8
2.2	Comparison of potential specific modulus values and ranges of natural fibers and glass fibers	9
2.3	Dried cogon grass	11
2.4	Extracted cogon grass fiber	11
2.5	Comparison of the specific modulus of the most common natural fibers and E-glass fibers	13
2.6	Structure of amylose and amylopectin	15
2.7	Chemical structure of PLA	18
2.8	Schematic representation of chitosan chemical structure	18
2.9	Typical Composite Materials	19
2.10	Usage of composite materials in aerospace structures in Boeing 787	20
2.11	Different Types of Metal Matric Composites	22
2.12	A ballistic vest with a silicon carbide–based material for its inner plates	24
2.13	SEM micrographs (40× amplification) of the fracture surface of TPS	29
2.14	The Young’s Modulus (E) of TPS foams with and without coating	30
2.15	The results of the Impact test izod of TPS foams with and without coating	31

2.16	SEM micrographs of different TPCS/LDPE composites	32
2.17	Mechanical properties of the different TPCS/LDPE composites with varies carrageenan contents	33
2.18	Mechanical properties of different TPCS/LDPE composites modified by carrageenan and/or cotton fibers	34
2.19	Young's modulus E as function of starch content in iPP and iPP/TPS composite	39
2.20	Yield strength σy as a function of starch content for iPP and iPP/TPS composites. nd — not determined	40
2.21	Elongation at the maximum stress εmax as a function of starch content for iPP and iPP/TPS composites	40
2.22	Sensory Properties of Beeswax	44
3.1	Methodology Flow Chart	47
3.2	Preparation of Cogon grass Fiber	49
3.3	Cassava Starch	50
3.4	Bottle of Glycerol from QRec Chemicals	51
3.5	Beeswax	53
3.6	Preparation of TPCS/Beeswax Mixture	55
3.7	Preparation of TPCS/Beeswax	56
3.8	Fabrication of TPCS/Beeswax reinforced with Cogon grass fiber	58
3.9	Final form of TPCS/Beeswax reinforced with Cogon Grass fiber	59
3.10	TGA Machine (Mettler Toledo AG)	60
3.11	Aluminium crucible pan	60

3.12	DSC machine	61
3.13	Flexural test on the Universal Testing Machine (INSTRON 5969)	62
3.14	INSTRON CEAST 9050	63
3.15	Cutting the specimen based on ASTM D638.	64
3.16	Universal Testing Machine (INSTRON 5969)	64
3.17	IR spectrometer (Nicolet 6700 AEM)	65
3.18	Scanning electron microscope (Zeiss Evo 18)	65
4.1	TGA curve of TPCS/Beeswax + CGF composite	69
4.2	DTG curve of TPCS/Beeswax reinforced with CGF composite	69
4.3	Glass transition temperature, Tg of TPCS/Beeswax reinforced with CGF composite	71
4.4	Tensile strength of TPCS/Beeswax + Cogon grass fiber	73
4.5	Tensile modulus of TPCS/Beeswax + Cogon grass fiber	73
4.6	Elongation at break of TPCS/Beeswax + Cogon grass fiber	74
4.7	Flexural strength of TPCS/Beeswax reinforced with Cogon Grass Fiber	75
4.8	Flexural modulus of TPCS/Beeswax reinforced with Cogon Grass Fiber	76
4.9	Impact Strength of TPCS/Beeswax reinforces with Cogon Grass Fiber	77
4.10	FT-IR spectra of the TPCS/Beeswax reinforced with the cogon grass fiber composites	79
4.11	SEM micrograph of fracture surface of TPCS/Beeswax + Cogon grass fiber composites	82

4.12 BCG Tray 83
4.13 BCG Tray 83
4.14 Application as the crayon packaging tray 83

LIST OF ABBREVIATIONS

TPCS - Thermoplastic Cassava Starch

PMC - Polymer Matrix Composite

E-GF - E-Glass Fiber

MMC - Metal Matrix Composite

CS – Cassava Starch

CMC - Ceramic Matrix Composite

TPS - Thermoplastic Starch

ASTM - American Society for Testing and Materials

TGA - Thermo Gravimetric Analysis

SEM - Scanning Electron Microscope

BC - Beeswax Composite

DTG - Differential Thermogravimetric Analysis

PLA - Polylactic Acid

TPSB - Thermoplastic Starch Beeswax

DSC – Differential Scanning Calorimetry

Tg – Glass Temperature

BCG – Biodegradable Cogon Grass

CGF – Cogon Grass Fiber

CHAPTER 1

INTRODUCTION

1.1 Background

Manufacture and distribution of plastics in the established and emerging nations seems to be growing rapidly. Since the 1950s, the production of plastic increased from 1.5 million tons to over 300 million tons in 2015, which is almost 200 times (Mrowiec, 2017). Characteristics of plastics are highly durable, lightweight, strong and economical. Plastics are commonly used in various of applications, to be made into various kind of products ranging from household and personal goods, packaging to construction materials. The consequences of extensive usage plastics result in plastic waste being present in the environment. Eventually, gives critical issues in environmental and human being (Mrowiec, 2017).

Thermoplastic starch (TPS) are the possible alternatives for petroleum-based polymer, due to its low density, low cost, the fact that they originate from abundant resources and its biodegradability. The research regarding TPS have been carried out widely with various sources of starch such as cassava, potato and corn (Bergel, da Luz, & Santana, 2017). The natural starch is required to undergo a hot compression molding with the presence of plasticizer, which is glycerol to become thermoplastic starch (Bergel et al., 2017). Nowadays, natural fiber reinforced polymer composites are widely utilized as an alternative to substitute present synthetic polymer or glass fiber reinforced material. The natural fibers that have been used such as flax, ramie, hemp, sisal and other else (Sanjay, Gopalakrishna, Arpitha, Yogesha, & Naik, 2016). For this study the utilization of TPS/beeswax are as the matrix because according to the previous study has shown that incorporation of beeswax improves the mechanical and lessen the moisture sensitivity (Zulfadhli & Zamree, 2018). Apart from utilize the TPS as matrix, this study uses the previous study modified TPS as matrix.

1.2 Problem Statement

Day by day, the concern about protection of ecological systems are rapidly growing. Non-biodegradable and environmental pollution are the side effects of petroleum based synthetic polymers. These polymers affect wildlife severely, due to its poor disposition (Gülsah, Gülnur, Mikhael, Céline, & Mualla, 2017). Recently, the excessive use of non-biodegradable plastics is very alarming. Non-biodegradable polymers cannot be decomposed by any natural processes. Besides that, these conventional polymers have long-lasting effects on landfills, where the toxic pollutants often contaminate the ground water. At the same time, non-biodegradable polymers also can lead to out-gassing.

Together with increasing environmental regulations, the depletion of petroleum resources acts synergistically to provide the impetus for new materials and products that are environmentally compatible and independent fossil fuel (Mohanty, Misra, & Drzal, 2005). Most of the plastics that are constantly being utilized are originated from petrochemical products. However, the increased demand for environmentally friendly plastics, such as bio-based plastics produced from renewable resources, and biodegradable plastics that are degrading in the environment to build a more sustainable society and managing global waste and environmental problems (Iwata, 2015).

Compared to synthetic thermoplastic, the TPS composition module is typically high. Elastic characteristics at low strains can be measured, although TPS has dependence upon moisture and elongation at break (Janssen & Moscicki, 2009). Proper modifications should therefore be implemented to enhance the properties of this material. Mixing with other polymers and enhancing with natural fillers and fiber may be potential modifications.

Fibers are strong and stiff, but because of their fibrous structure are hard to be used in load-bearing applications. The fibers act as a reinforcement in fiber-reinforced composite materials by providing strength and rigidity in the structure, while the plastic matrix adhesives the fibers in order to make appropriate structural components (Mohanty et al., 2005). Cogon grass fiber (also known as *imperata cylindrica*) is a rhizomatized, permanent pantropical herb, which takes on the advantage of moist, short, severe, dry seasonal alternating conditions typical of southeastern Asia. Cogon grass is cheap and attractive feedstock to be used in feed and production of bioenergy (Haque, Barman, Kim, Yun, & Cho, 2016). According to the study by (Srinivasababu, Kumar, & Reddy, 2014), cogon grass have specific properties, renewable nature, low cost and biodegradability over traditional reinforcement materials.

This study if therefore driven by improving the properties of thermoplastic cassava starch, by expanding the potential use of cogon grass fiber and lastly by producing fully biodegradable material that can be safely disposed in the environment.

1.3 Objectives

The primary purpose of this study is to establish and identify materials that are biodegradable and entirely sustainable depends on natural resources. The definite objectives are:

1. To develop thermoplastic cassava starch/beeswax reinforced with cogon grass fiber.

2. To investigate the thermal properties of thermoplastic cassava starch/beeswax reinforced with cogon grass fiber.
3. To determine the mechanical properties of thermoplastic cassava starch/beeswax reinforced with cogon grass fiber.

1.4 Significance of Study

The justification of this study are as follows:

i. The findings from the current study can provide the new knowledge in developing of biodegradable polymer from the modification of thermoplastic cassava starch/beeswax reinforced with cogon grass fiber.
ii. The development of the biodegradable polymer by strengthen its properties in this study will provide another solution to overcome the environmental problems by replacing the petroleum-based polymer.
iii. The problem that connected with petroleum-based polymer like environmental pollution during manufacture and disposition can be diminished with the implementation of fully bio-composite derived from cogon grass fiber and thermoplastic cassava starch/beeswax.
iv. Furthermore, this study also applies the cogon grass fiber, beeswax and cassava starch in developing of bio composite. Thus, added more value to the existence of cogon grass fiber.